Liquefied petroleum gas plant maintenance: a case study of gangway failure analysis

Pereira, Eloi Dos Santos; Alkali, Babakalli; Niculita, Ioan-Octavian

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Eloi S Pereira, Babakalli M Alkali and Octavian Niculita

Glasgow Caledonian University, G4 0BA, Scotland
Telephone +44 (0)141 331 3576
Telefax +44 (0)141 331 3690
E-mail Babakalli.alkali@gcu.ac.uk

Abstract

Complex equipment fail from time to time and subsequently leading to losses in production output, and hence requiring repair and replacement of equipment components. In order to reduce the number of frequent failures, periodic inspection of equipment can be conducted to identify and rectify any minor defect that may otherwise cause failure. This paper investigates several failures on Liquefied Petroleum Gas (LPG) Gangway in a Liquefied Natural Gas (LNG) Processing Plant. The plant is observed during operation and weekly inspection of the Gangway is conducted, prior to ship loading to meet Marine, Operation and Maintenance requirements. During the facility operations a number of issues related to the reliability and safety of operating the LPG gangway have been identified. An evaluation of all safety, operability, and maintainability issues associated with the LPG gangway is conducted. Some of these incidents involved the gangway impacting ships and causing damage to the gangway and ships. A Root Causes Analyses (RCA) approach is used to analyse historical failure and maintenance data. Reliability and downtime analysis is conducted in order to determine the failure pattern of the gangway system as associated cost. A reliability model is proposed in an attempt to determine optimal cost effective, inspection schedule for safe and reliable operation of the LPG gangway.

1. Introduction

The Gangway is a safety critical system in a Liquefied Natural Gas (LNG) Processing Plant. The gangway is a structural platform that allows personnel to embark and disembark a ship when it is docked. It consists of a bulwark, telescopic ladder and a tower. The gangway is powered by a hydraulic power pack. The gangway towerabout 20-30 meters high and, consists of tower frame, lift mechanism, pulley block, gangway, electrical control equipment, hydraulic control equipment. The telescopic ladder can travel up and down the tower. The bulwark is connected at the end of the telescopic ladder, (Gangway Manual 2012) [1].

The reliability of a machine is always less than its parts, when one part fails the whole machine fail. With many parts in a machine, there are many chances of failure. To improve the reliability of a series of parts, it is important to improve the reliability of each part, in order to get its maximum life, (T. R Moss 2005)[2]. The grapgh in Figure 1 show system and component failing rate and the strategies to improve the reliability of each parts.

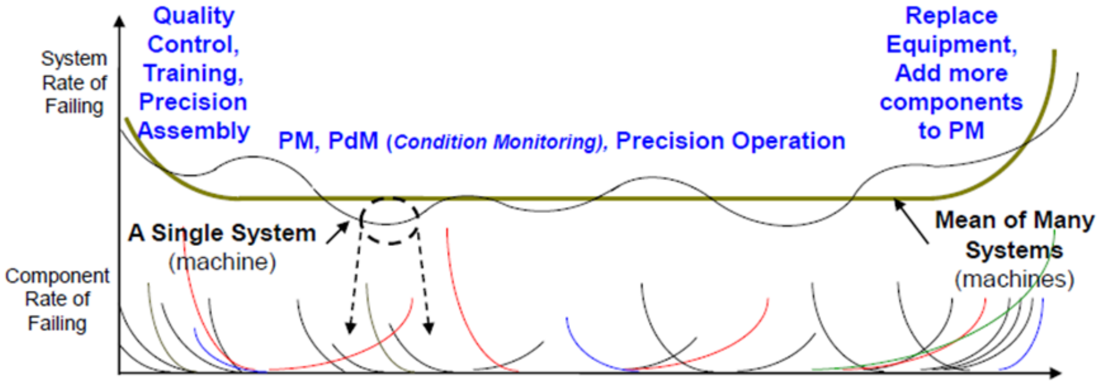


Figure 1 illustrate system and component rate failing

On the other hand the use of Failure Mode and Effect Analysis (FMEA) is not new and has been considered by many researchers to assess system failures. The most common is the Reliability Centered Maintenance (RCM) concept which determines the type of maintenance tactics to be applied to an asset, while it answers the question of "what type of maintenance action needs to be taken" the concept is discussed extentively in (Moubray, J.2012)(3). The RCM approach take a longer-term perspective to make decisions on asset replacement in order to improve reliability in the best interests of businesses and organisational performance. Some maintenance models are suitable to reduce the number of breakdowns, models subject to group or block policy, aging replacement policy, and inspection policy, are discussed in (Jardine, A. and Tsang, A. 2013)(4). The safe operating conditions of the equipment should be checked on a regular basis. Worn or broken parts should be replaced immediately by original spare parts to safeguard a reliable functionality of the equipment.

However in this paper, a broad brush root cause analysis approach is considered for the analysis of the gangway system. The main goal is to determine an optimal cost effective replacement and inspection policies .

2. Gangway Structural framework

The structural framework of the gangway and its constituent part is presented in the diagram Figure 2. Although the Gangway consist of a variety of mechanical, electrical and instrumentaltion and control system. A a review of historical failure and maintenance associated with these system is presented and reliability analysis of gangway failure data is discussed.

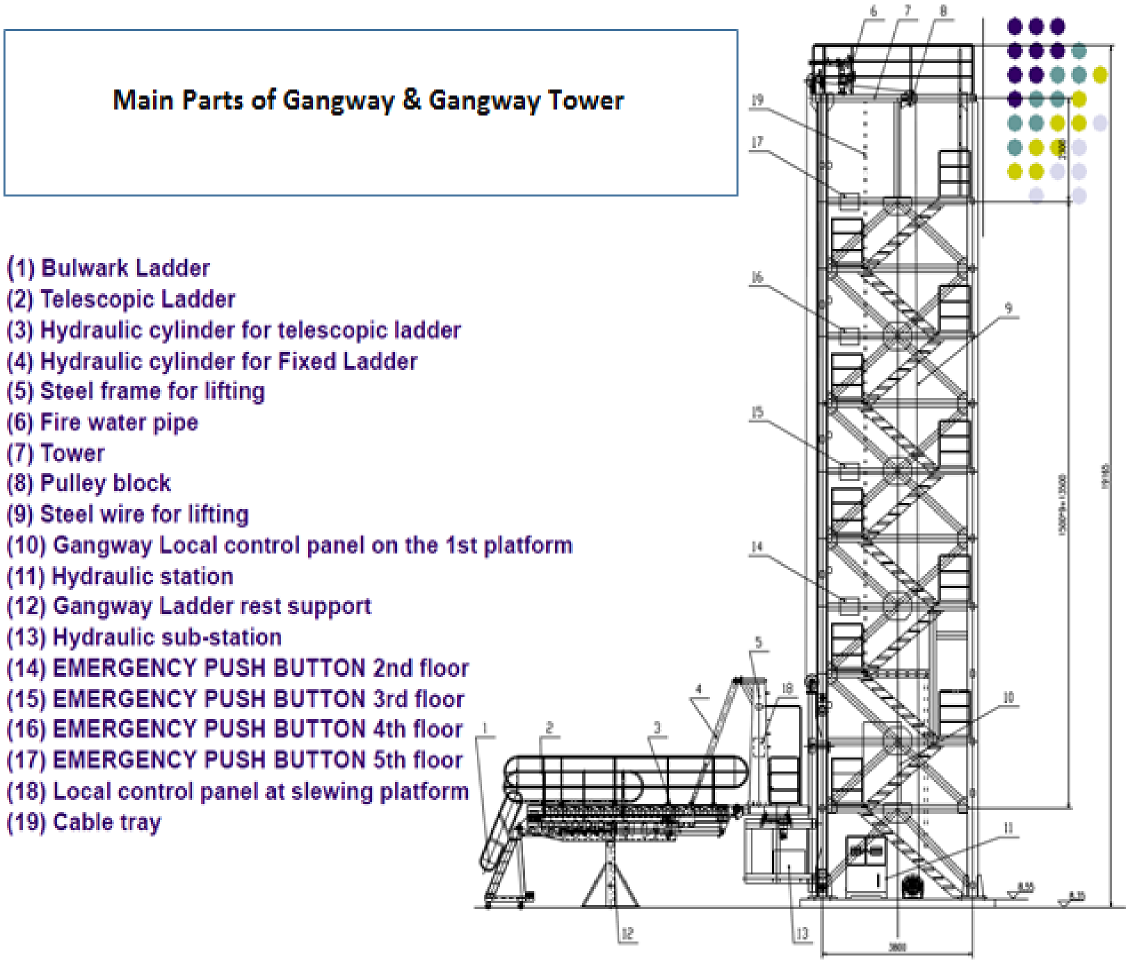


Figure 2 Structural framework of Gangway and Gangway Tower *(Gangway Manual 2012)* [1].

3. Failure history

Historical failure information from 2016 – 2019 is reviewed, (SAP Failure History Data) [5]. Failure assessment conducted in this paper focuses on the following systems:

- Cable around the drum
- Ladder Weld joint detached
- Lower Limit Switch
- Pin Limit Switches
- Programmable and ESDL PLC Logic Control
- Hydraulic Cylinder oil leak

The systems above have higher impact upon failure resulting to significant losses. However, the failure frequency of the gangway mechanical and instrumentation system is conducted and shown in the graph in Figure 3.

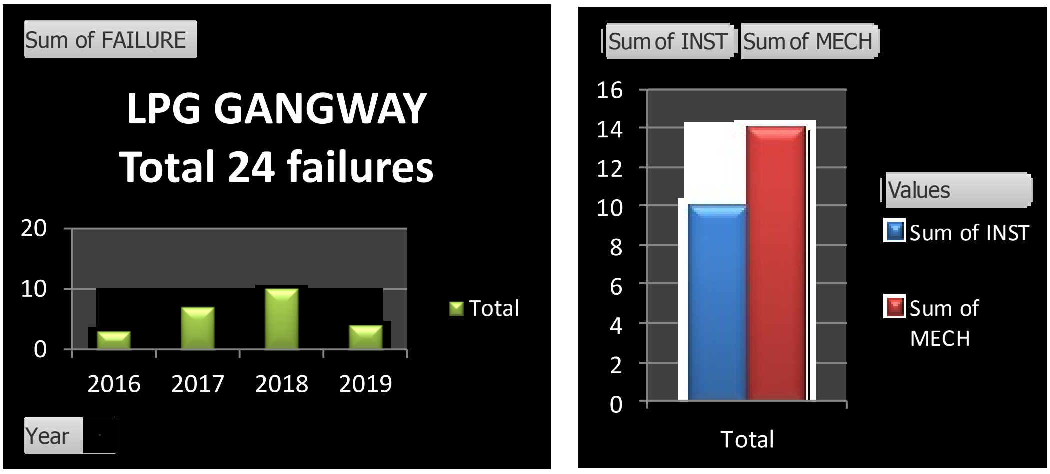


Figure 3 LPG Gangway mechanical and instrumental failure data

3.1 *Cable*

Root cause analysis of the cable is conducted and the failure modes leading to cable failure is caused by twisted cable when the gangway is moving down to a parking position. The observed incident is as a result of the following;

I. Cable replacement with a different cable size with larger diameter
II. Safety pin not extracted fully which cause the platform to jam

The proposed task to ensure reliable operation is to:

Carry out visual inspection prior to starting up the Gangway, check the steel wire condition, pulley block, and direction of pump motor rotation. Alignment marks for the fixed ladder position to the rotating platform as shown in the diagram below in Figure 4. The yellow mark will ensure that the hydraulic motor stop by the set point.

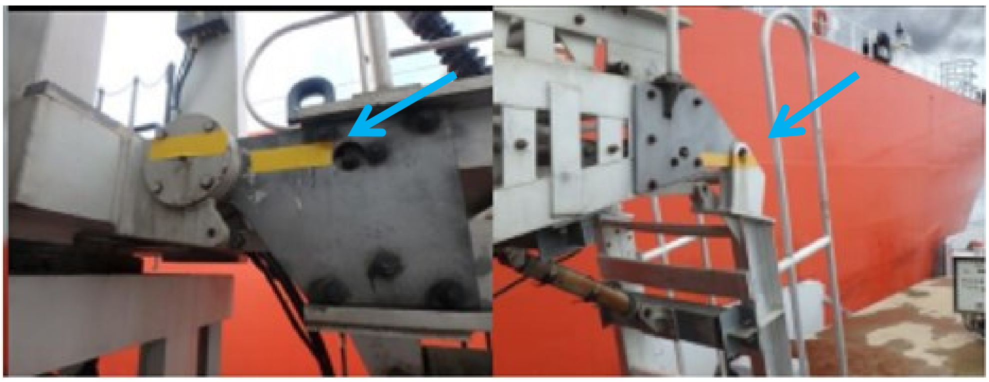


Figure 4 Gangway structure at parking position

3.2 Fixed ladder weld joint detached from the hydraulic cylinder

Fixed ladder weld joint of the Gangway detached from the hydraulic cylinder bracket while the Operators where performing the weekly routine test. According to the assessment from the collected data, we observed the following root causes:

- poor welding quality
- Improper low quality fabrication at the hydraulic joint bracket which have negatively influenced this incident.
- Supports which mainly hold the load of the gangway has major cracking and tearing at the base metal.
- Crater cracks, porosity and pinholes are observed during dye penetrant test on the existing welds.

The diagram in Figure 5a show the welds had failed as a result of crack where the support was attached to the fixed ladder frame and the worst affected were the welds attaching the front box section. The back box section welds had partially failed leaving the support mechanism in danger of falling away from the fixed ladder frame.

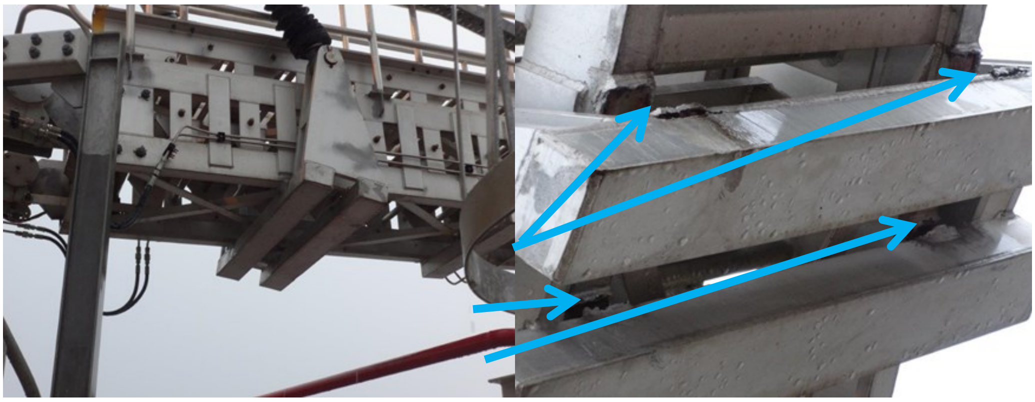


Figure 5a. Weld crack

Other significant damage was found at the front box section seam welds. The box sections two angle beams welded along the long seams. Where the seam was directly under the failed weld areas as shown in Figure 5b, we observe that it has split leading to significant damage and distortion.

Figure 5b. Weld detached from the hydraulic cylinder

3.3 Lower limit switch

The gangway tower has is a single limit switch installed at level 1 of the tower to prevent the gangway from continuing to unspool cable when the gangway reaches level 1 Figure 1. If the lower limit switch fail to activate this could lead to an unsafe condition. The investigation conducted indicate that the incident was not due to a limit switch issue and was instead caused because the gangway was not centered and was resting on the sides of the parking stands causing it to not reach the lower limit switch. However upon review of the installation it was observed that a backup lower limit switch is required to ensure that the switch functions properly to provent potential safety hazards. The installation has redundant limit switche at the top level 5 as shour in Figure 6 below.

Figure 6 Single limit switch at Level 1, and redundant limit switch at level 5

3.4 Pin limit switches

The pin limit switches were also investigated. The pin limit switches have two functions. All pins must be "out" in order to raise and lower the gangway. Also the pins must be "in" at a particular level to operate the gangway controls. A example of pin limit switch in and out is shown in Figure 7. When attempting to raise and lower the gangway if all pin limit switches are not satisfied as "out" the control system will prevent the operator from raising or lowering the gangway. If one pin is not properly aligned to satisfy the limit switches it can be difficult for the operator to identify which is causing the problem and align it so that the gangway can be operated. This is particularly problematic when the gangway needs to be raised or lowered quickly when landed on a ship. In addition the current configuration of the pin limit switches can allow the pins to come in contact with the proximity sensors. This can cause damage to both the pins and proximity sensors in the past.

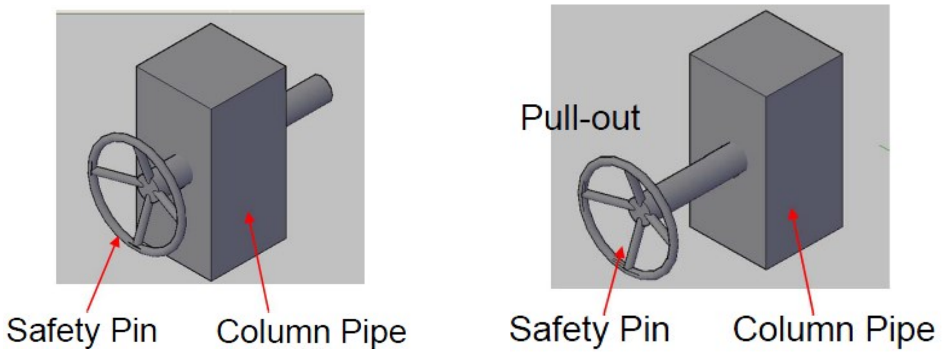


Figure 7 Pin limit switch inserted in, and Pin limit switch Pulled out

3.5 Programmable ESDL logic controller(PLC)

The control logic lower the gangway automatically from Level 2 to Level 1 and if it is not lined up correctly for parking there are a number of potential problems that could occur. Requiring the operator to hold the push button would ensure they are monitoring the gangway as it is lowered and allow the movement to stop immediately when release the push button.

On the other hand the gangway PLC logic raise and lift the gangway away from its current location during an Emergency Shut-down Loading (ESDL). This is to lift the gangway of the ship if an ESDL occurs in order to allow the ship to safely release. However the ESDL logic will also raise the gangway when it is in the park position. This has been noted to occur in the past and when it does occur causes the gangway to impact the adjacent mooring dolphin. This have caused structural damage to the gangway in the past as observed in the historial data information.

3.6 Hydraulic cylinder oil leak

Oil leak on hydraulic ram cylinder (luffing cylinder) was investigated and we found the first seal failure as shown in the diagram in Figure 8, the possible causes of failure is as result of;

- Ageing process, seals are expected to be used until the end of useful life time.
- Seal was not replaced since the plant start-up, nor replaced when mechanics identified the oil dripping issue.

- There was no preventive maintenace in place to replace the internal parts (seals) of the hydraulic cylinder.

Figure 8 hydraulic ram cylinder oil leak (seal failed)

4. Reliability assessment

4.1 Weibull analysis

The Weibull distribution is one of the most widely used model for the analysis of reliability data. The flexibility that make the Weibul model very attractive for the reliability anaysis is its ability to deal with constant, decreasing and increasing rate of occurrence of failure, (T.R Moss 2005)[(2)].

The Weibul model cumulative distribution function is given as

$$F(\mathrm{t}) = 1\text{-exp } [-(t/\eta)^{\beta} \qquad (1)$$

A Wwibul distibution is fitted to the failure and maintenace data. The data consist of both preventive maintenace and corrective maintenance. The distribution overview plot of the Weibull fillted model is presented in Figure 9. The shape prameter is approximately 1.6 which signifies that the preventive maintenace conducted in the gangway is not effective. This show that the gangway exibit an increasing failure rate.

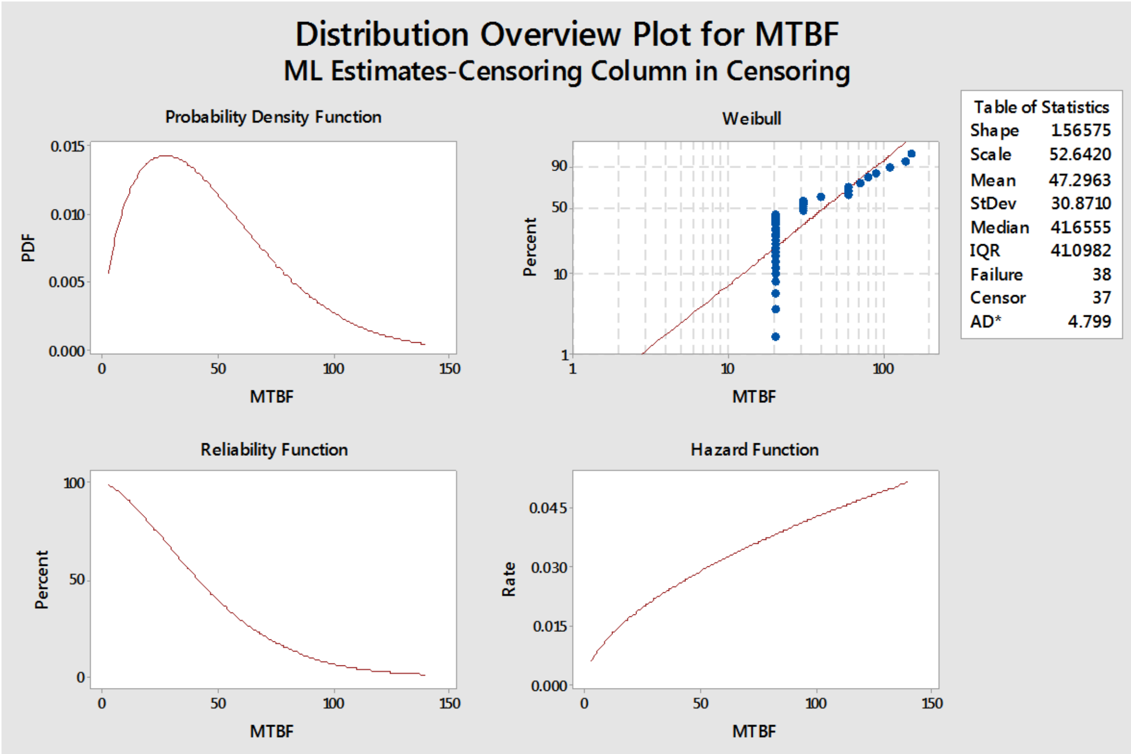
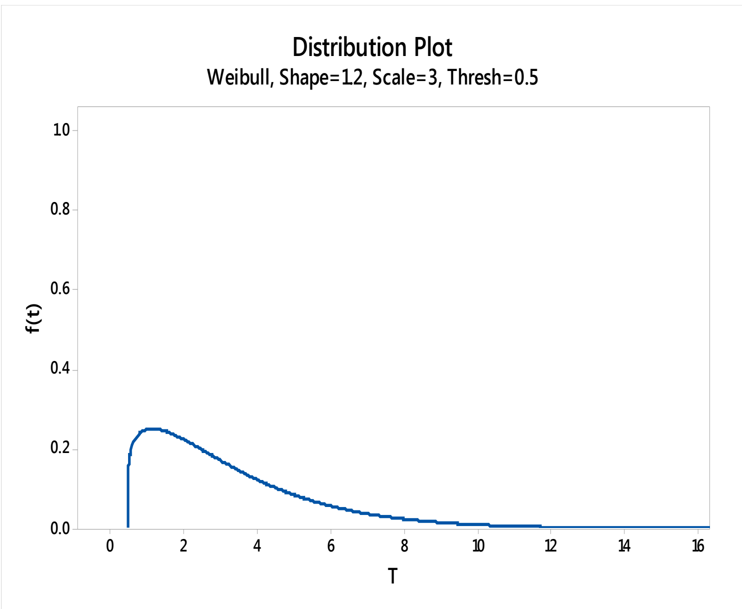


Figure 9. Weibull distribution overview plot

A Weibul extreme value distribution is fitted to the data and the fitted distribition is shifted. The Shifted Weibil distribution seem to be an adequate model with a threshold parameter 0.5. However the shpe paramter still show that the maintenace conductd on the gangway is not effective.



Following the fitted model to the failure data dwn time analysis is conducted

4.1 Downtime analysis

The gangway downtimes required to conduct maintenance varies with time. The variation relate to the type of component. The gangway consist of mechanical, electrical and instrumentation and control systems. The total number maintenance on the systmes in hours is presented in Figure 11 blow. Notice that the mechanical systems has the highiest number of maintenance hours followed by instrumentation and electrical systems.

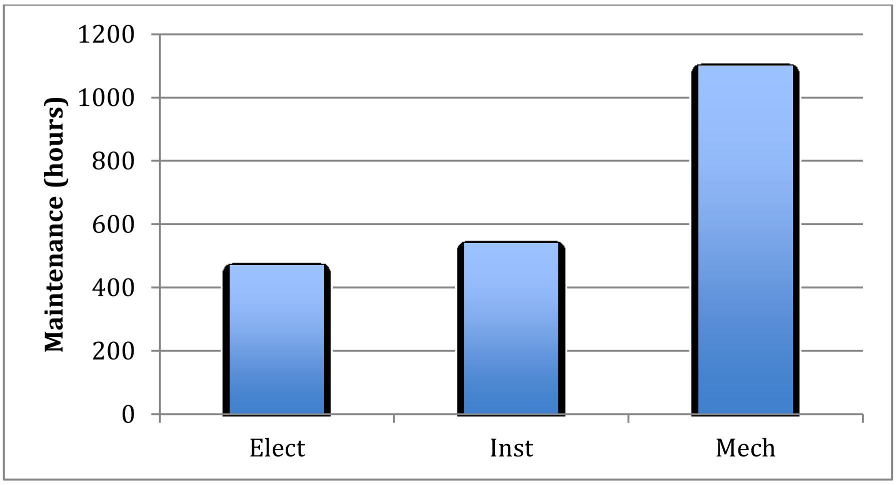


Figure 11 Critical systems maintenance duration (hours)

The graph in Figure 12 give the downtime hours comparison of the expected normal duration to conduct maintenance and replacement and the manhours required to do the work.

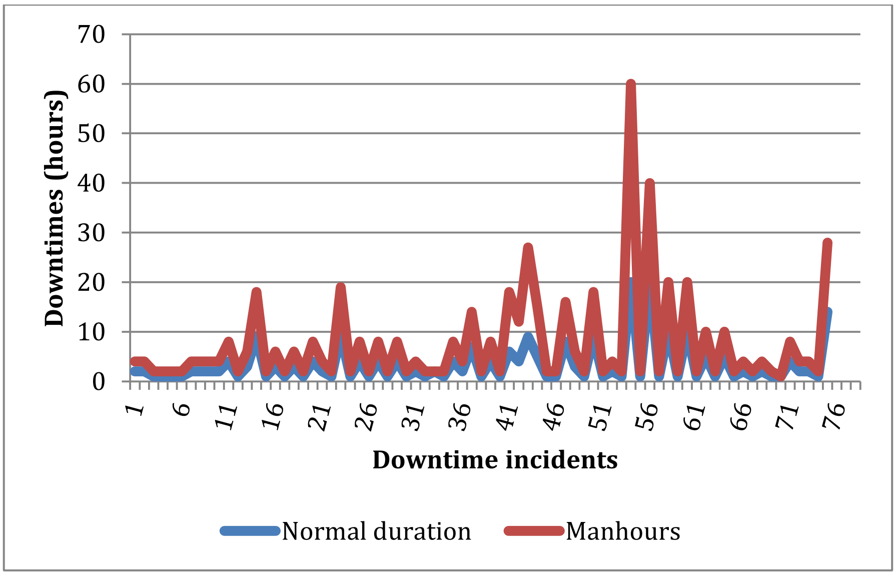


Figure 12 Downtime hours against downtime incidents

5. Conclusions

Root cause analysis of the gangway critical systems is presented in this paper. The issue of inadequate maintenance practices of the gangway systems. Technical description of the systems and historial failure data information of LPG gangway is analysed. Reliability analysis of the data is conducted by fitting a Weibull model to give a better insight about the failure patterns, and hence determine appropriate maintenance strategy. However the Weibull model result show an increasing failure rates, which suggest that the Planned Maintenance (PM) task for LPG gangway is not effective. A common approach to improve the reliability of system is through preventive replacement of critical components within the system. Downtime analysis show an increasing labour manhours and no significant effect on reduction in failure rate. Further analysis of the gangway data is still on going and we intend to preset the result in future publications.

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